Alteration of type-G wellbore cement during carbon sequestration: An experimental case study

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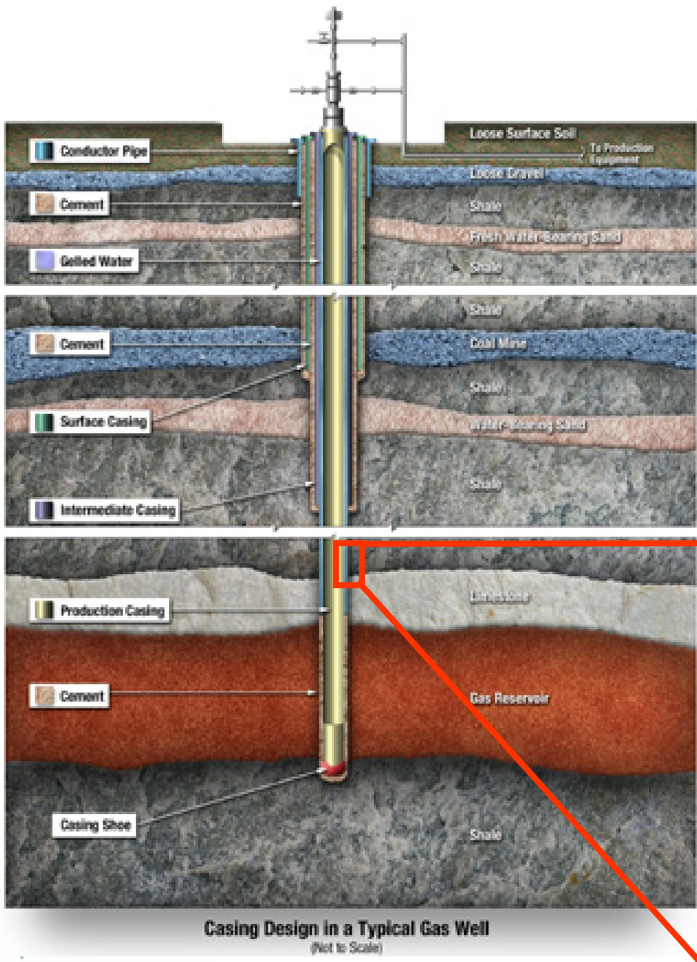
Objectives for this study

- Experimental study of the wellbore class-G cement-formation water-$SCCO_2$ system under in-situ reservoir conditions during carbon sequestration
- How does reaction with $SCCO_2$ affect the geophysical properties (e.g. porosity and permeability) and integrity of the cement?
- Can Alkali-Carbonate Reactivity (ACR) processes occur in wellbore cement during carbon sequestration?

Wellbore integrity



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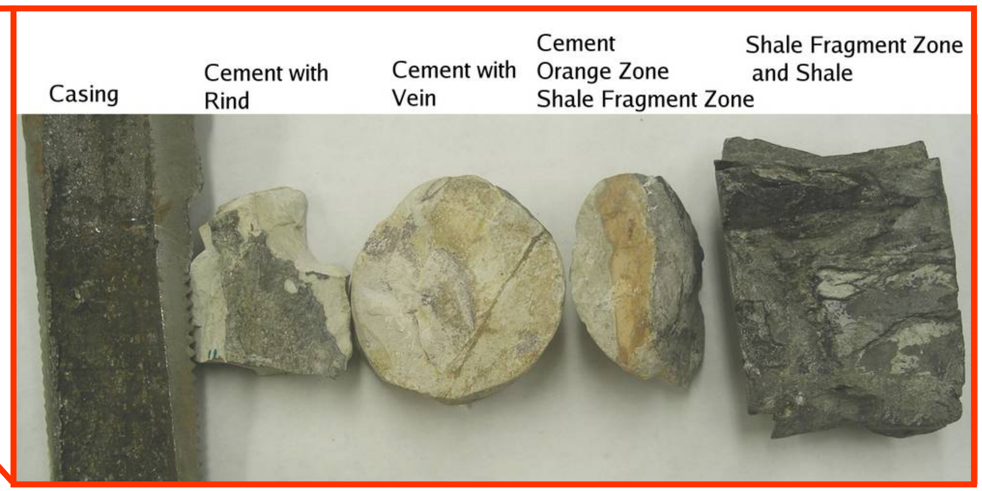
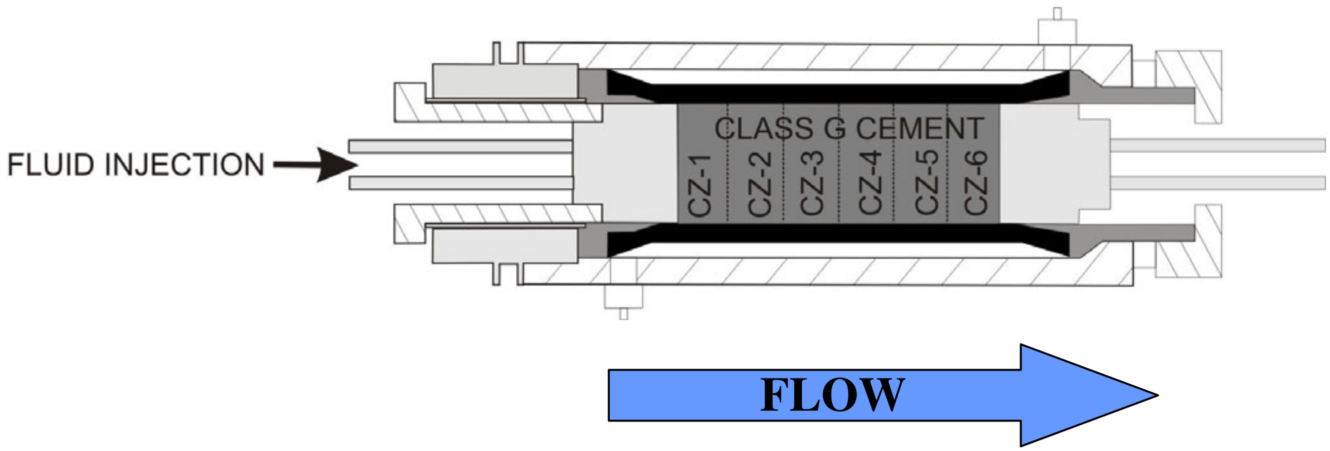
Potential risks:

- Wellbore flow
- Cement interactions with supercritical CO_2 and/or acid gases
- Cement interaction with formation brine



Experimental Setup



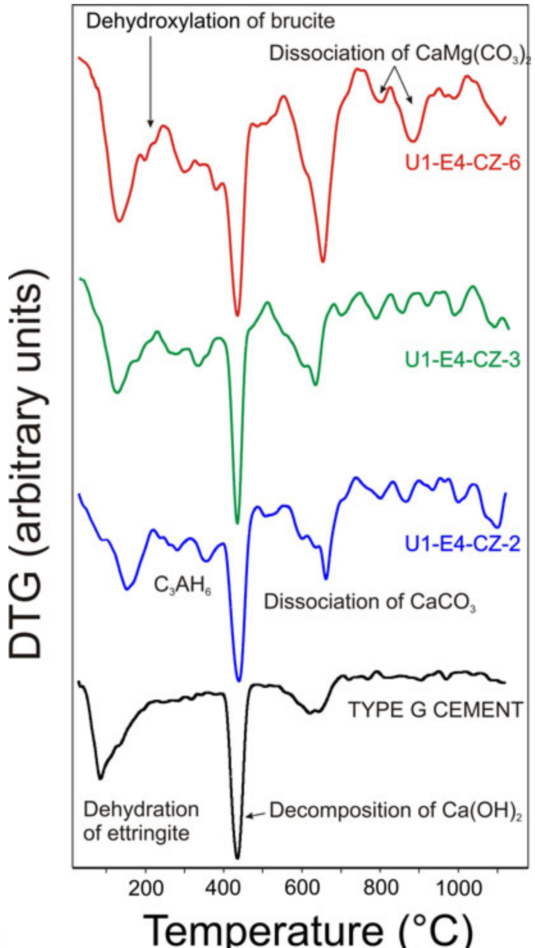
EXPERIMENTAL SETUP:

Hassler vessel
Injection pressure 2880 psi
Pressure gradient 40 psi
Confining pressure 3800 psi
Temperature 54°C

PROCEDURE:

Saturation with 1.65 M brine over 31 days
Injection of $SCCO_2$ over 141 days

Mineralogy

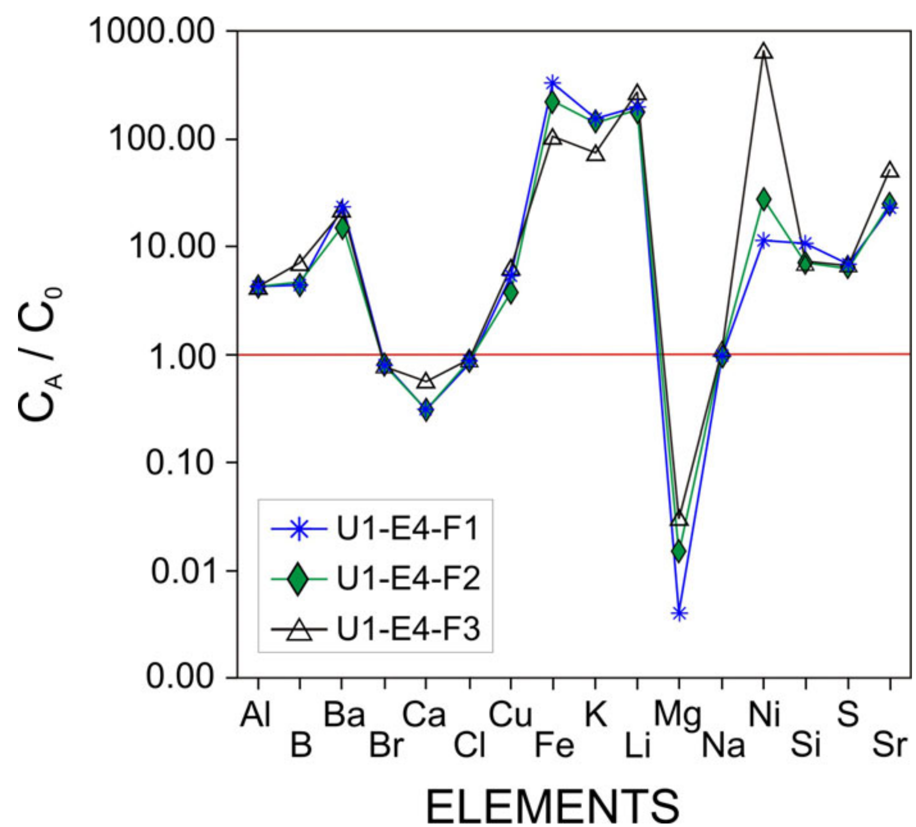


	CLASS-G CEMENT	U1-E4-CZ1	U1-E4-CZ2 TO U1-E4-CZ5	U1-E4-CZ6
$Ca_5Al_2(SiO_4)_3(OH)_4$	X	X	X	X
$Ca(OH)_2$	X	X	X	X
$Ca_3Al_2(OH)_{12}$	X	X	X	X
$Ca_{1.5}SiO_{3.5} * H_2O$	X	X	X	X
$Ca_2(Al,Fe)_2O_5$	X	X	X	X
Ca_3SiO_5	X			
$Al(OH)_3$	X			
$Ca_4Al_2O_6Cl_2 * 10\ H_2O$		X	X	X
$Mg(OH)_2$				X
Calcite	X	X	X	X
Aragonite				X
$Ca\ Mg(CO_3)_2$				X

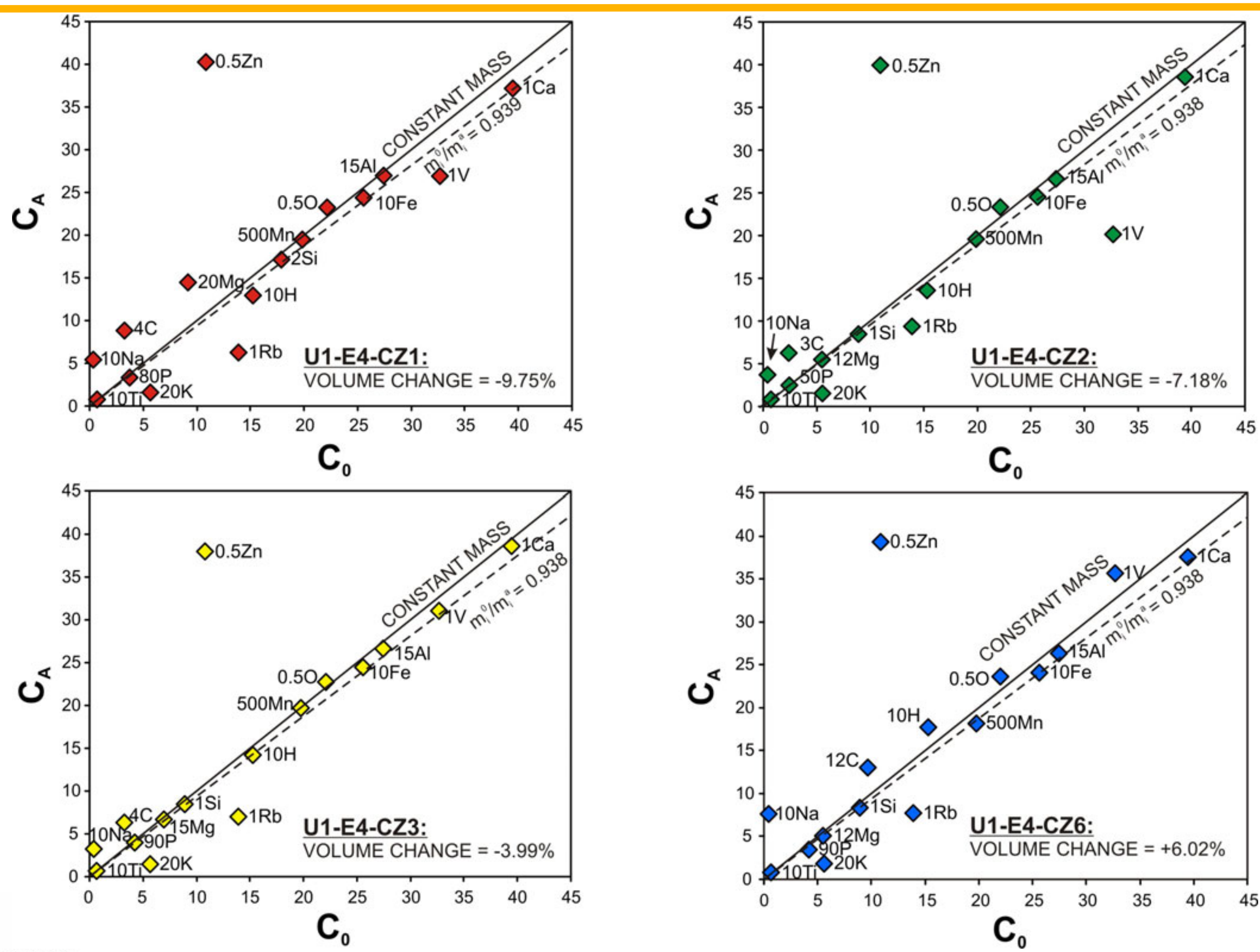
Fluid Chemistry

Brine Composition:

pH	6.61
HCO_3^-	1181 ppm
Cl^-	53493 ppm
SO_4^{2-}	507 ppm
Na^+	32525 ppm
Ca^{2+}	4284 ppm
Mg^{2+}	724 ppm
Ionic strength	1.651
TDS	88953 mg/kg



Whole-Rock Geochemistry



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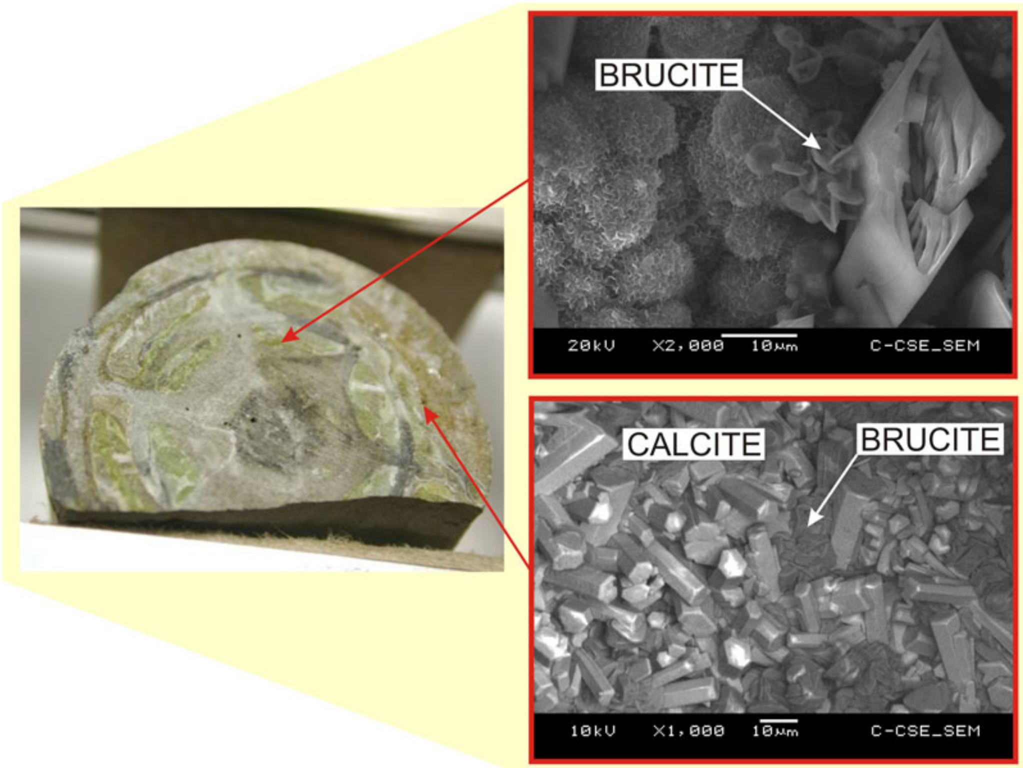
Alkali-Carbonate Reactivity Products at the opposite side of the core



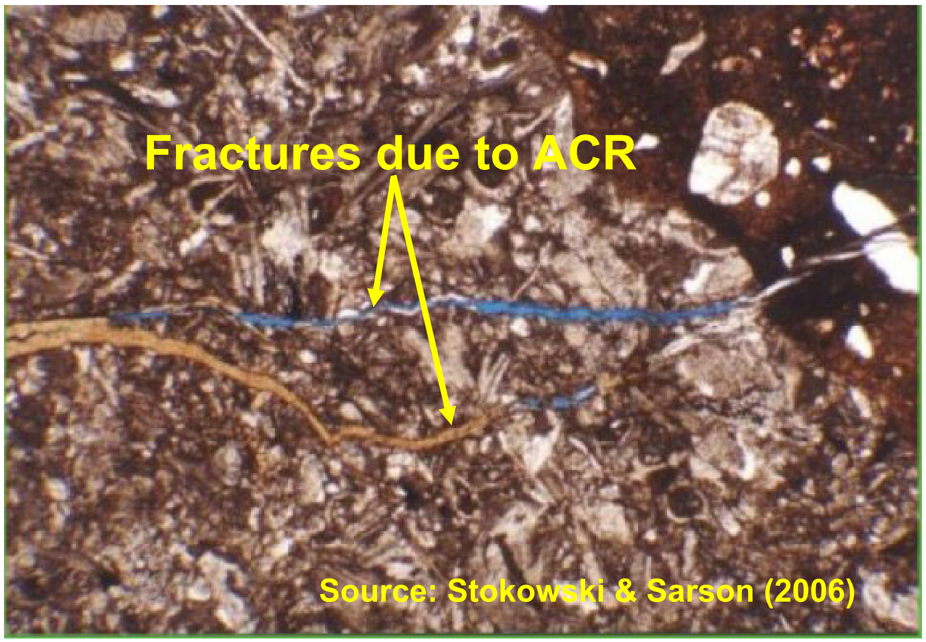
XRD RESULTS:

CEMENT PHASES	wt%
Portlandite	15
Brownmillerite	9
Hydrocalumite	7
Katoite	6
Ca_2SiO_4	7
Ca_3SiO_5	4
Calcite	6
Aragonite	2
Brucite	4
Amorphous	40

ACR-TYPE REACTION (“DEDOLOMITIZATION”):

$$CaMg(CO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + 2CaCO_3$$

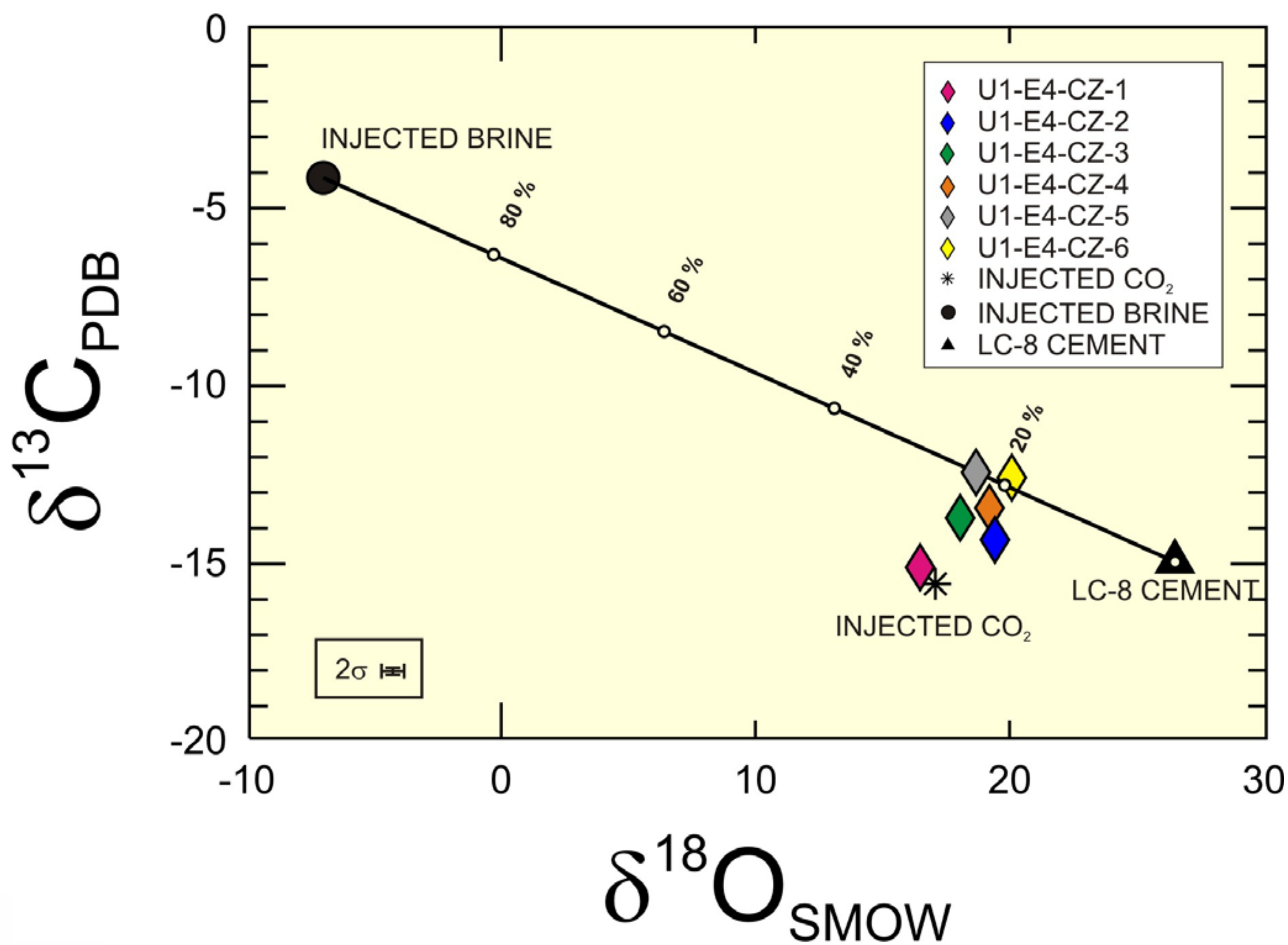
Alkali-Carbonate Reactivity



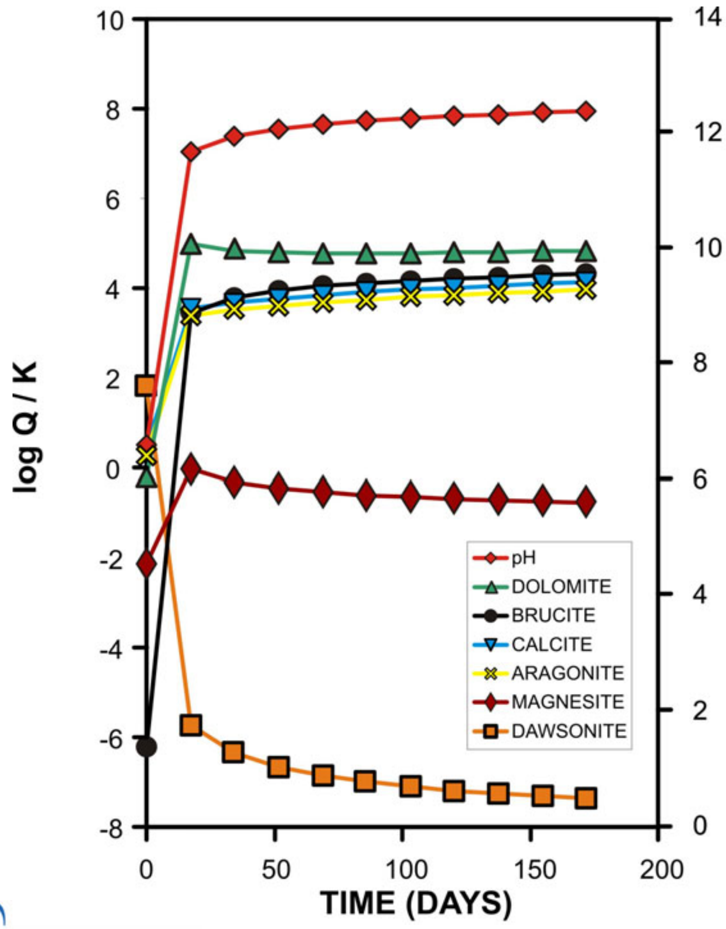
Results of ACR:

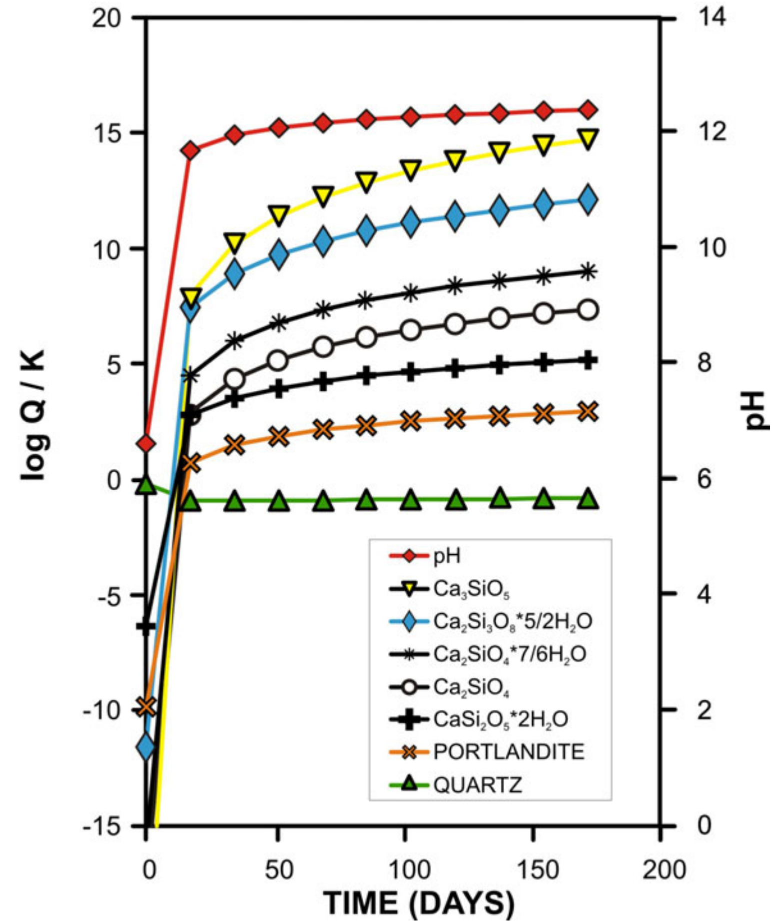
- Expansion of structural members due to differential volume change
- Formation of fractures and loss of bond between aggregate particles and cement paste
- Brucite and Ca-rich deposits in cracks, voids, and paste

Stable Isotopes as an Indicator for the Carbonation Process of the Wellbore Cement

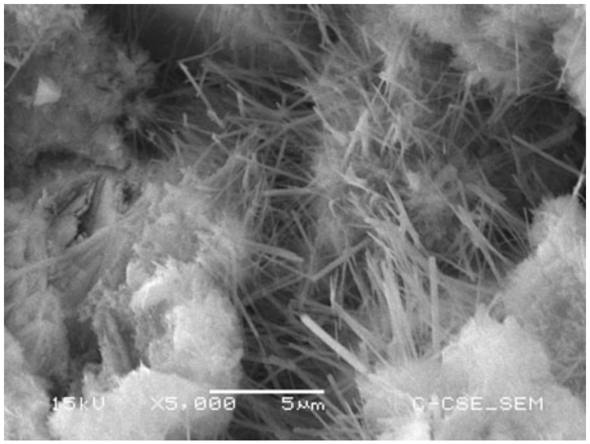


Geochemical Modeling



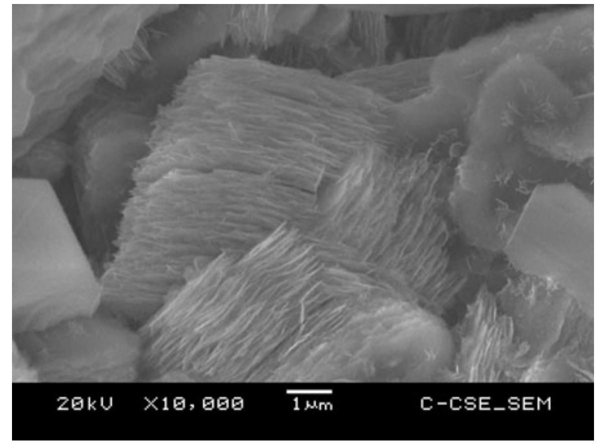


Changes in Cement Texture



$SCCO_2$

Brine



- Changes in the texture of the cement but no formation of an orange-colored carbonation zone
- Increase in weight by 7.13% and decrease in porosity by 11.2%

Conclusions

- Not every Portland-based wellbore cement shows a complete carbonation during the reaction with $SCCO_2$ & brine
- Portlandite and C-S-H present throughout the core
- No formation of an orange alteration zone
- CO_2 does not appear to have penetrated through the length of the core (2.39 cm) during the 172 day experiment
- ACR-like processes can occur during carbon sequestration processes

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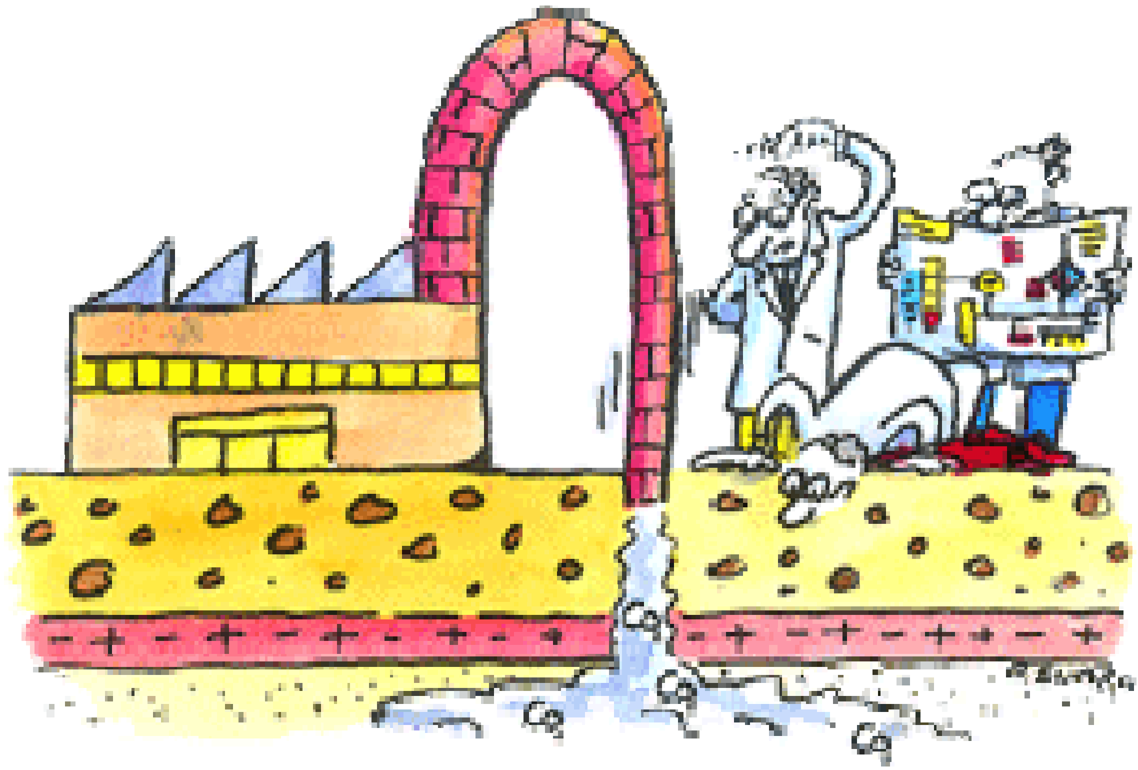

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Thank you very much for your attention !